
The microwave system of the SpinQuest polarized target setup

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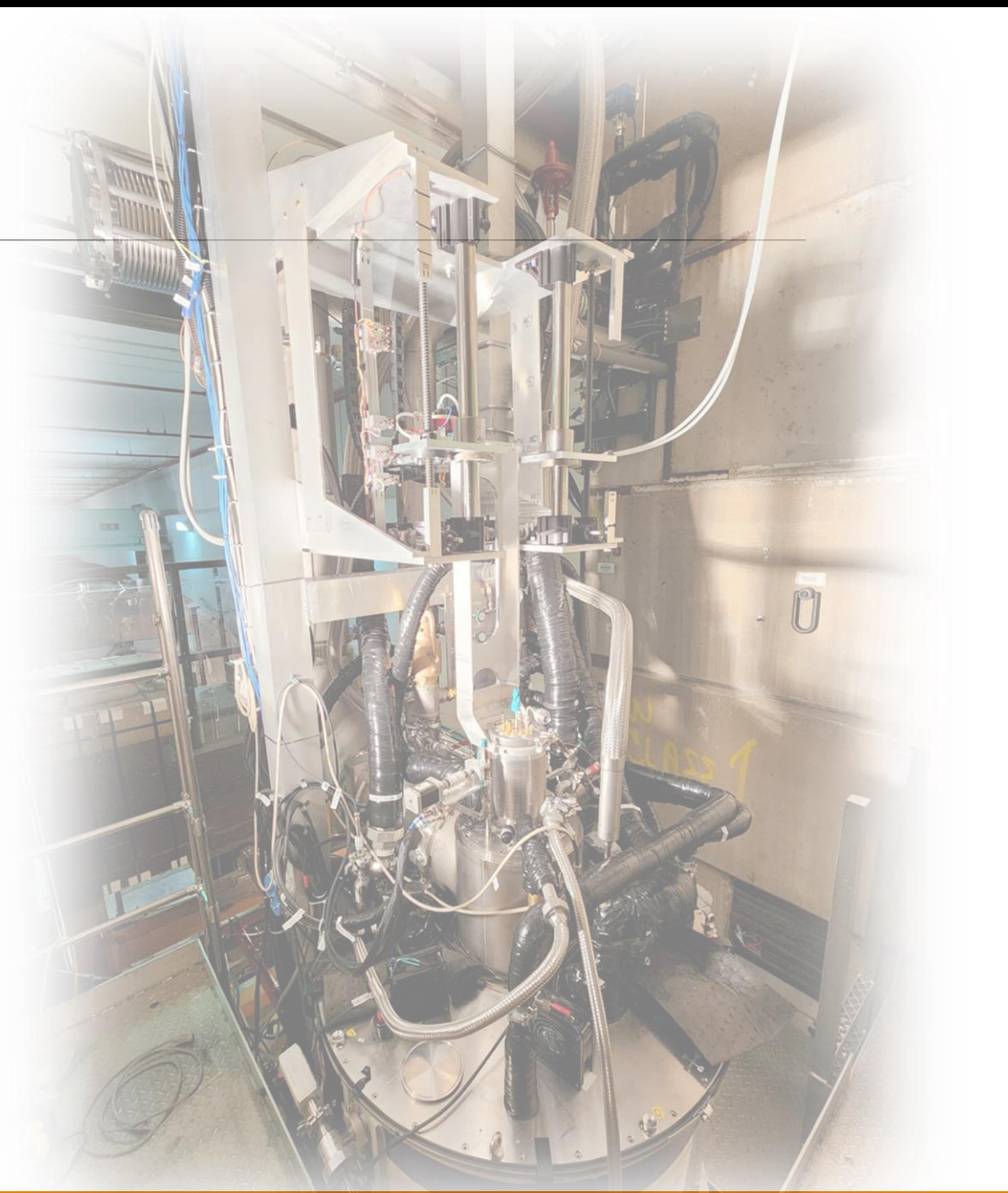


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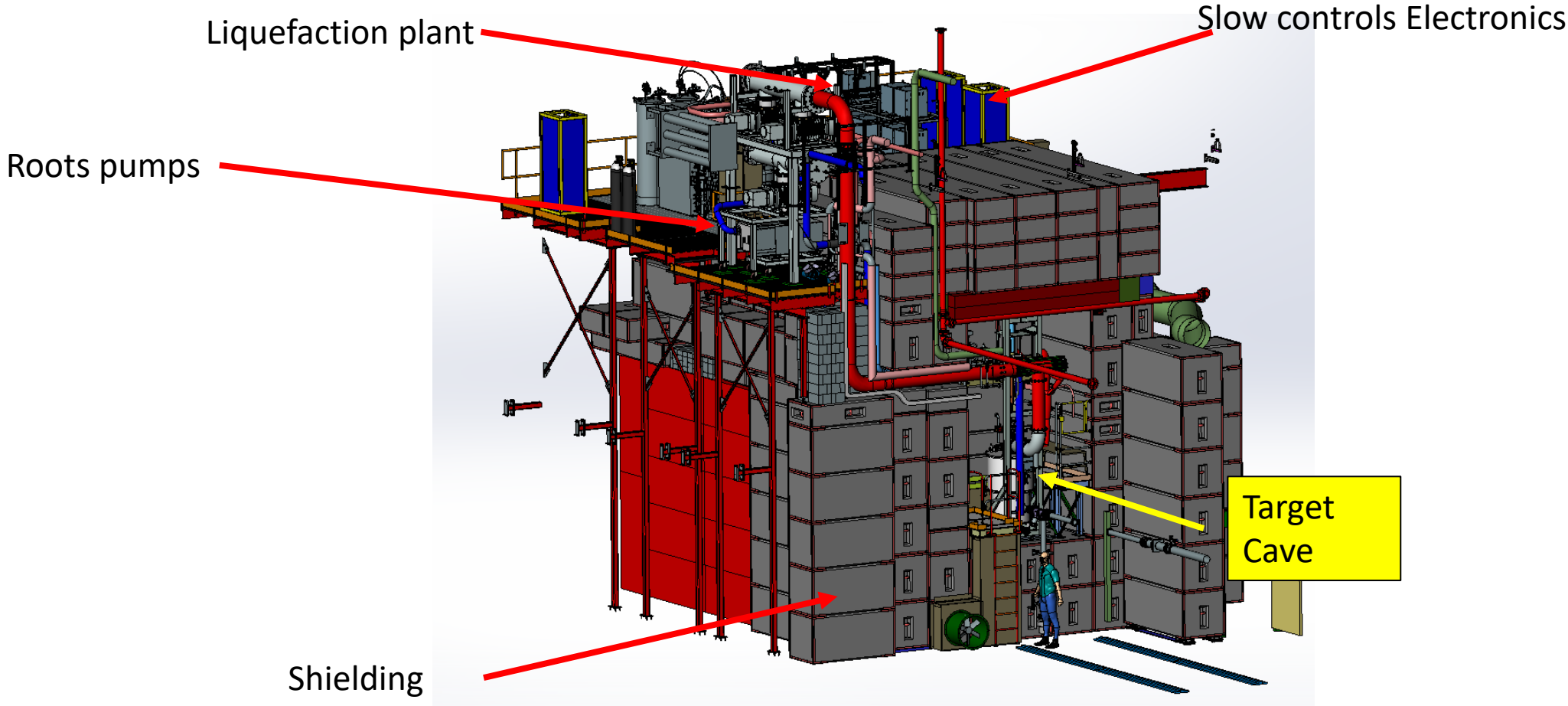
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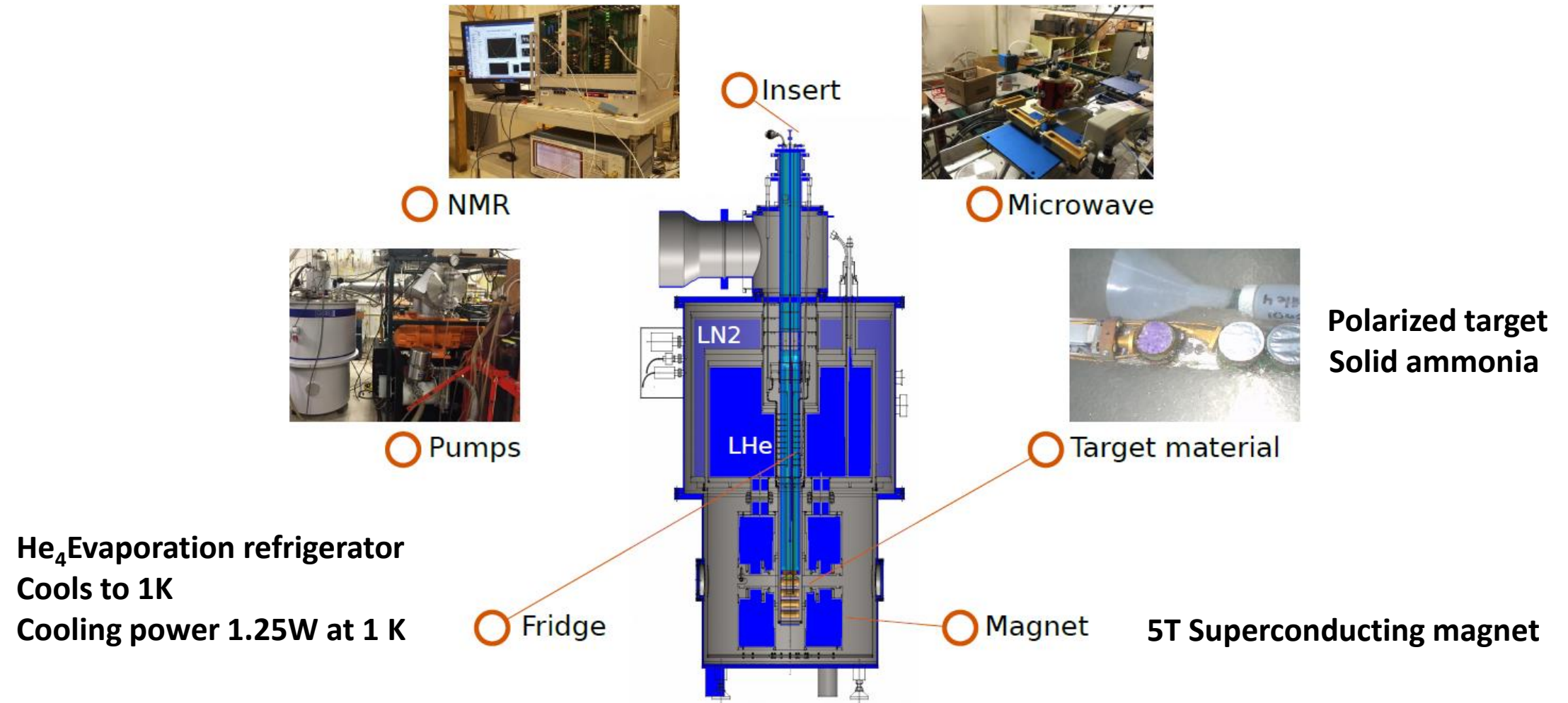
- Overview of the target system
- Microwave generator
- Waveguides setup and the target insert
- Frequency controlling system
- Polarization data



Overview of the target system



Key components of the target system



Overview of the Microwave system

The primary task of the microwave system

- enhance the polarization of the target material (NH_3)
- Maintain the polarization when during the beam interaction

The thermal equilibrium (TE) polarization of the material is given by

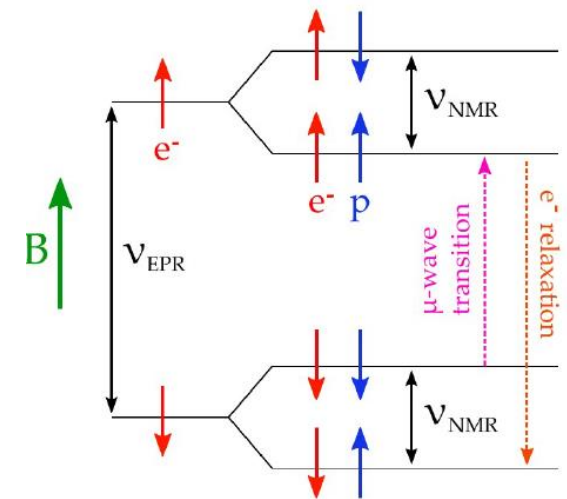
The polarization of the protons are enhanced by applying microwave signal

Positive and the negative polarization can be achieved by changing the microwave frequency appropriately

This mechanism is known as the dynamic nuclear polarization (DNP)

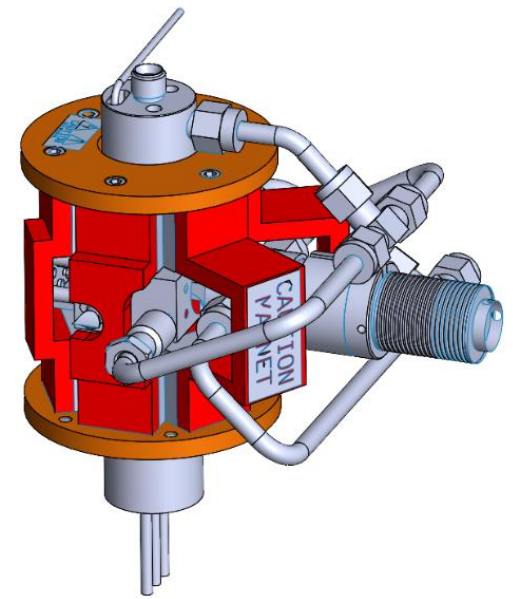
$$P_{TE} = \tanh\left(\frac{\mu B}{kT}\right)$$

μ – Magnetic moment
 B – External Magnetic field
 T – Temperature
 k – Boltzmann constant



The Microwave generator

- Variable frequency Extended Interaction Oscillators (EIO) is used to generate microwaves signal.
- EIO is powered by Varian VPW 2838A2 power supply
- The operating frequency of the EIO is determined by the cathode voltage.
- The output frequency is fine tuned by the changing the size of the resonant cavity inside the EIO.
- The maximum power output 10 W
- The EIO is cooled using an external chiller
- The microwave body temperature and the chiller water flow rate is in the interlock for safety



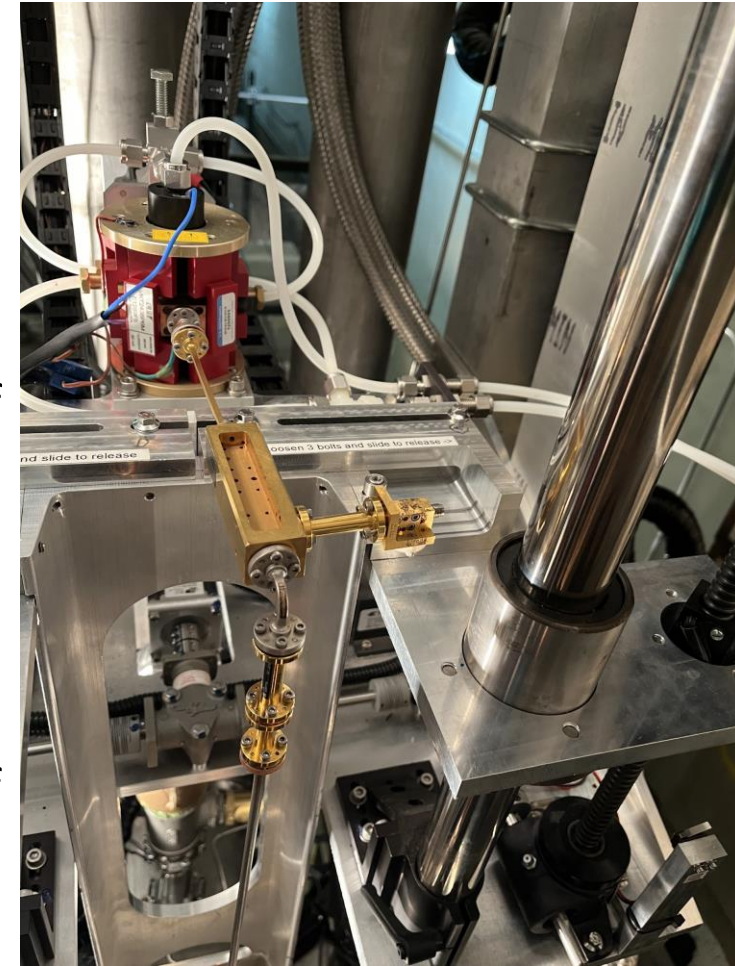
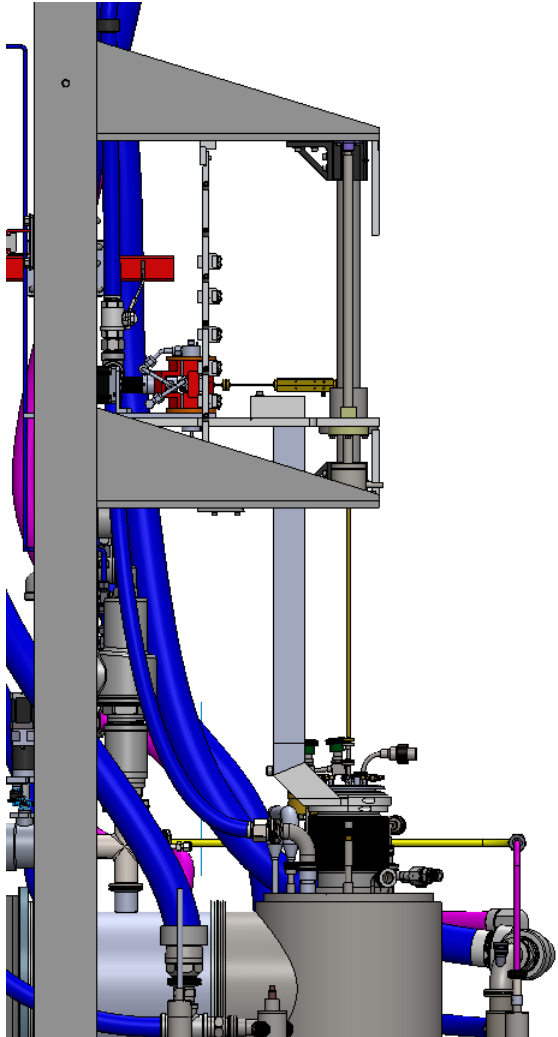
Target insert and Waveguides

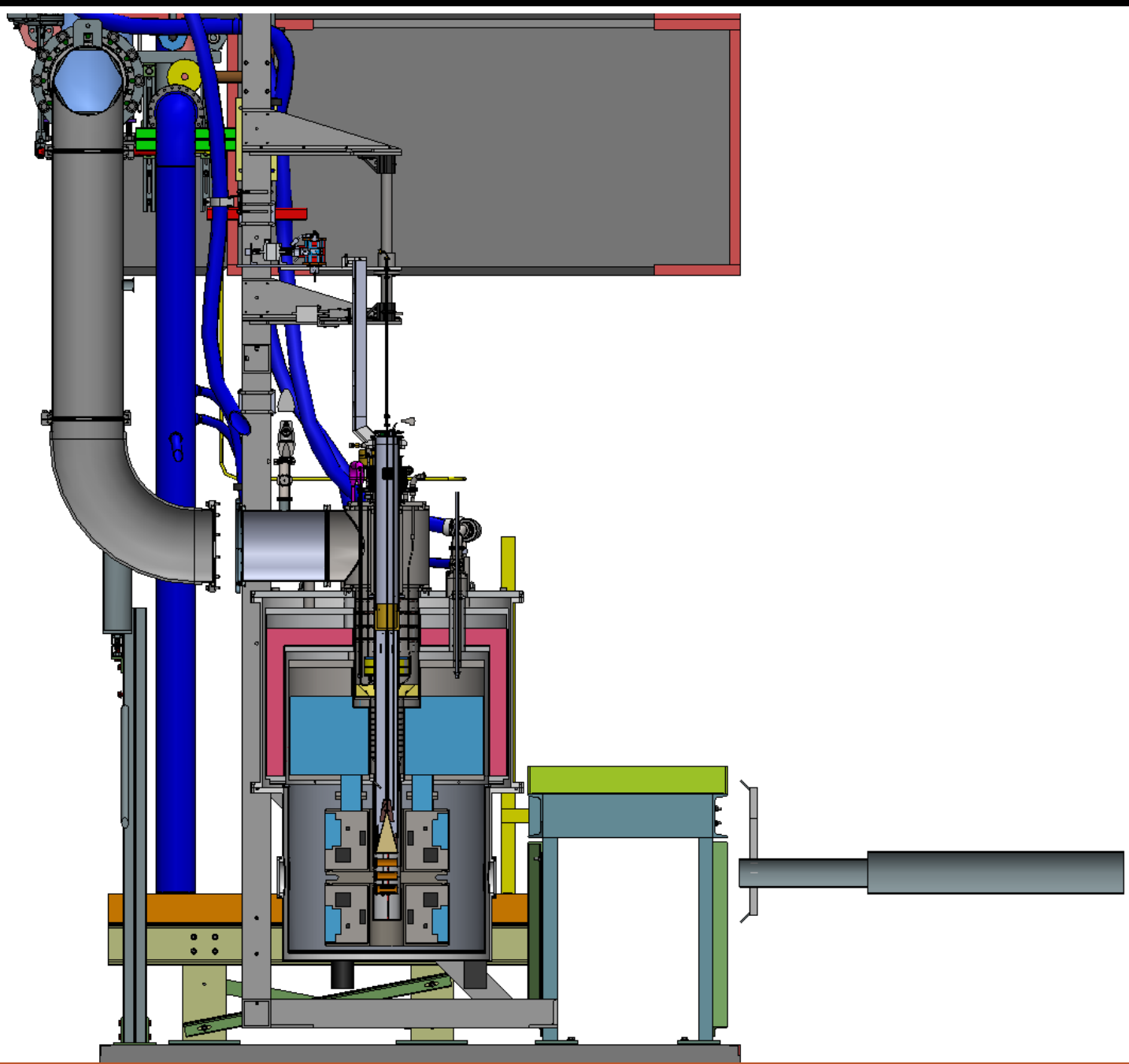
The EIO is located on the target lifter setup, and it is coupled to the target insert through wave guides and splitters

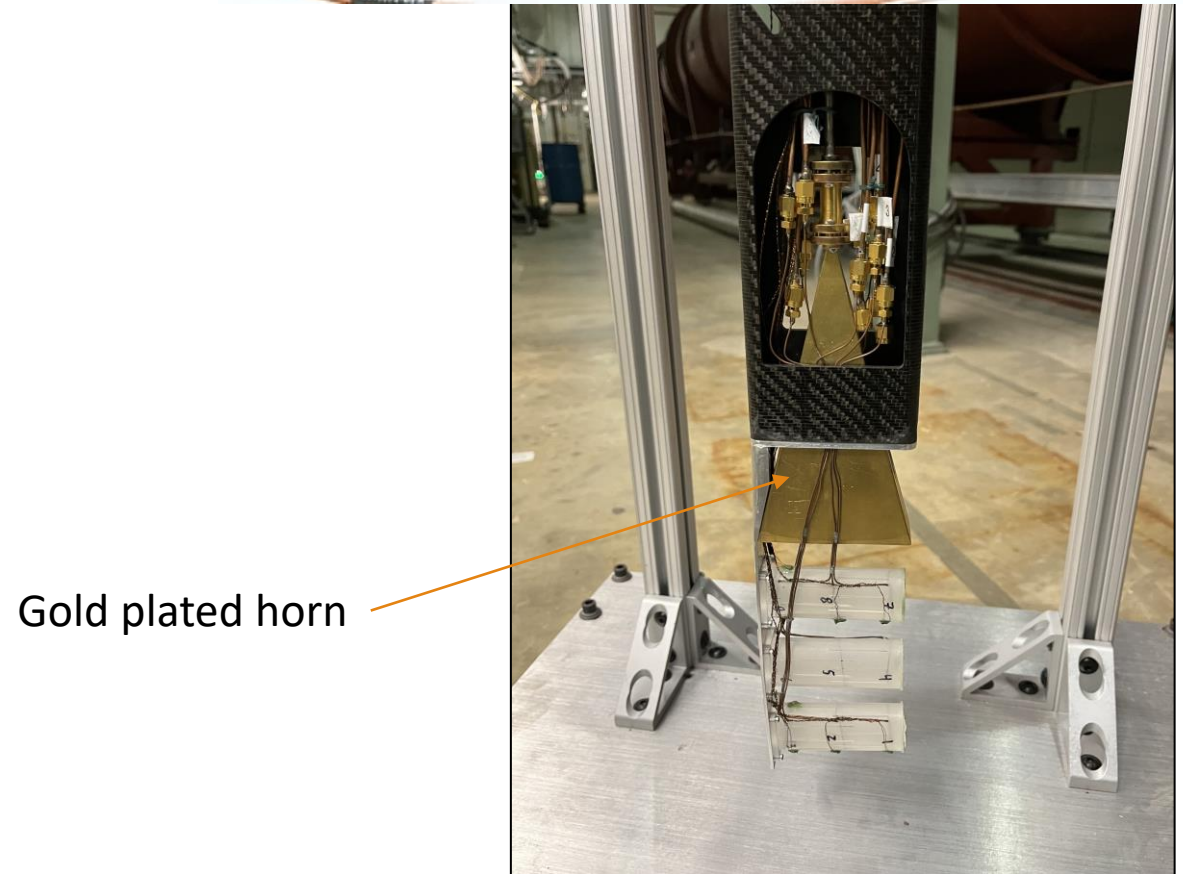
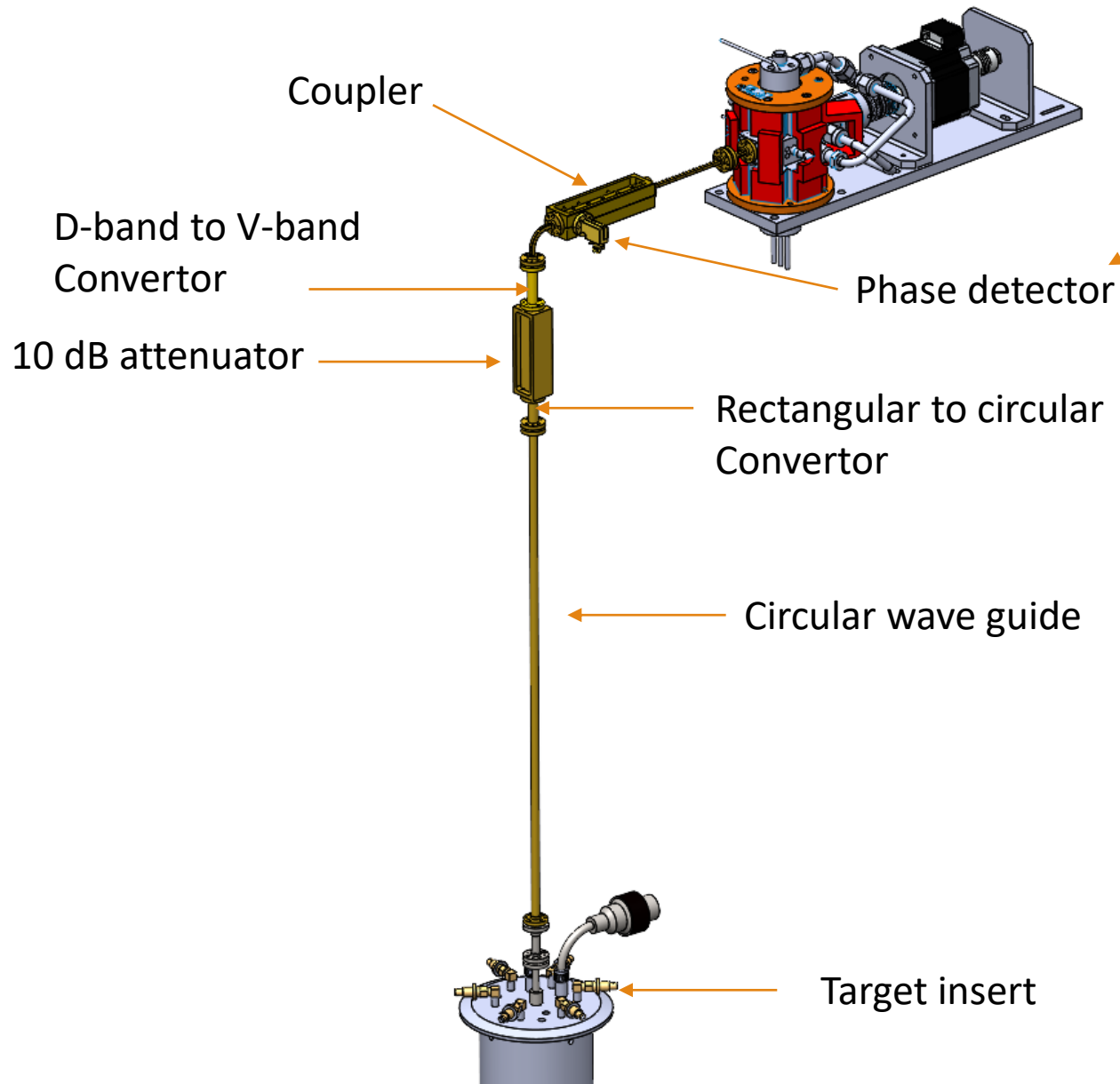
The target insert contains three(3) cells

The circular wave guide starting from the top flange of the target insert is terminated at a gold-plated horn on the target cell assembly

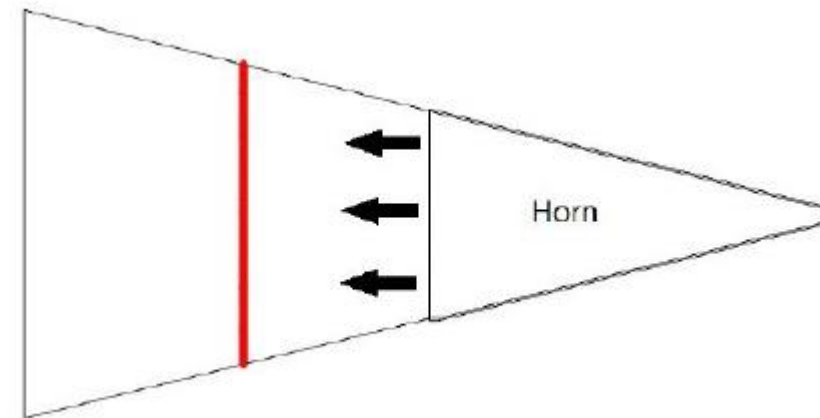
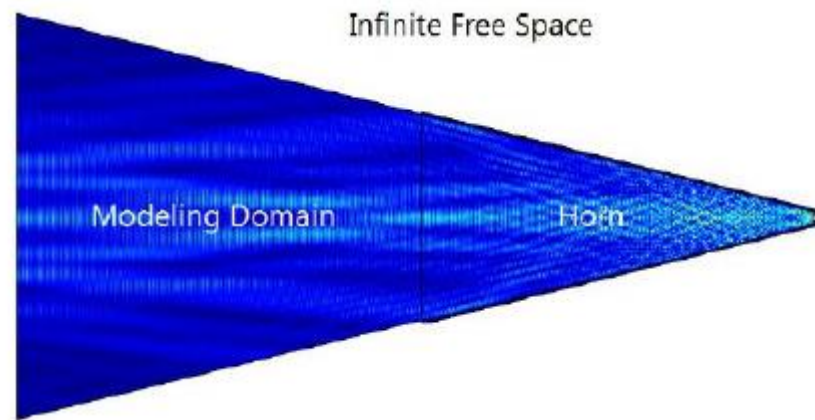
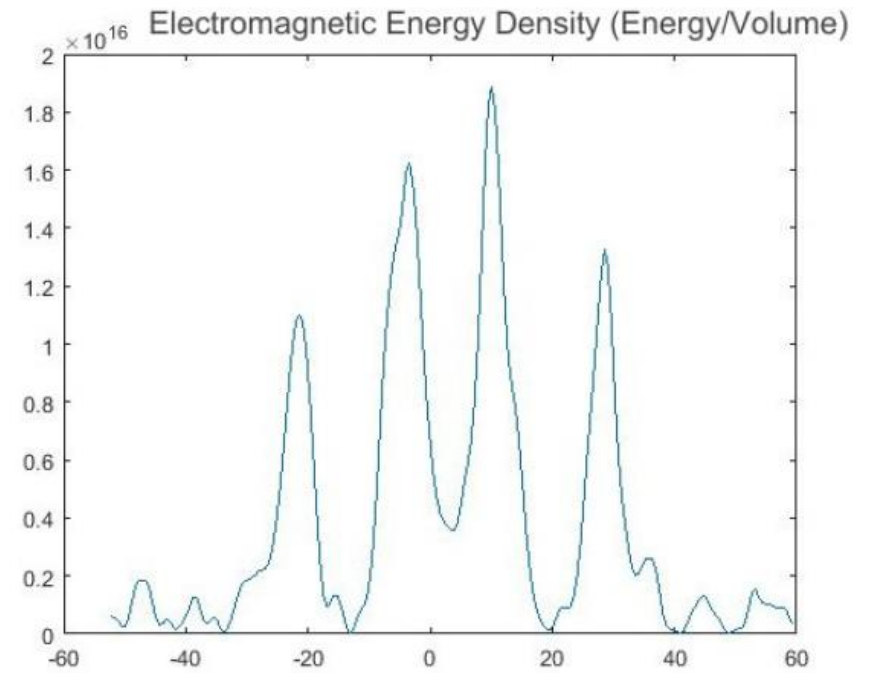
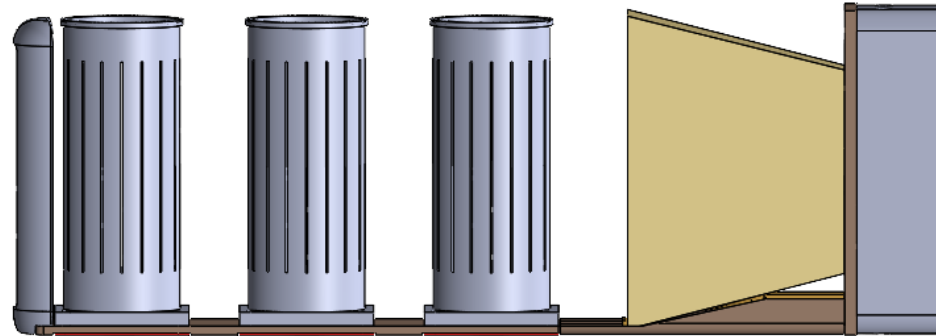
Each target cell contains three (3) NMR coils to measure the polarization. The top and the bottom cells contains cernox sensors measure the temperature of the materials





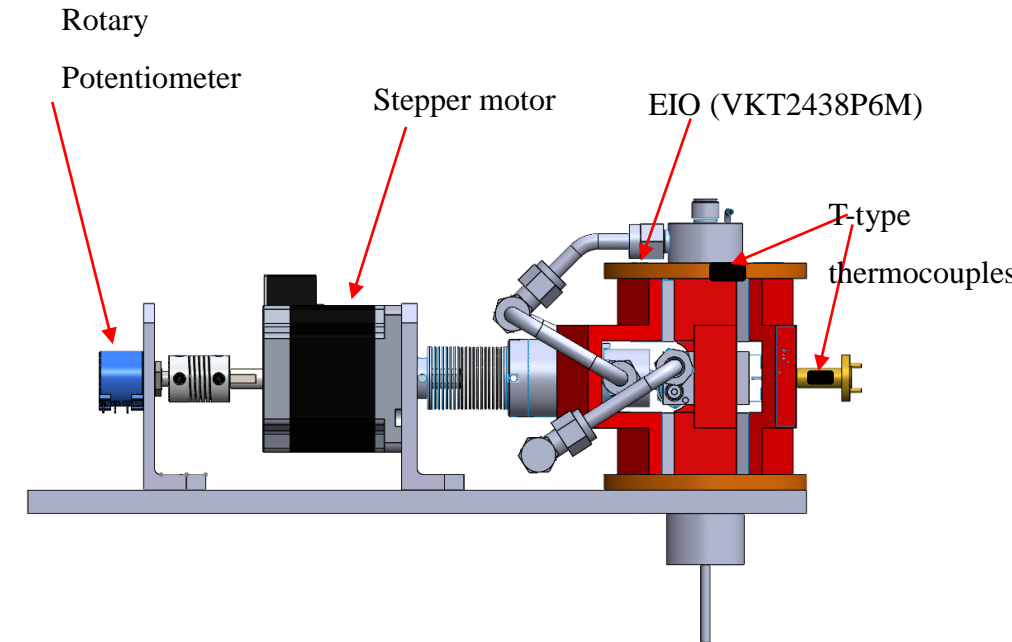


Microwave Profile of the Horn



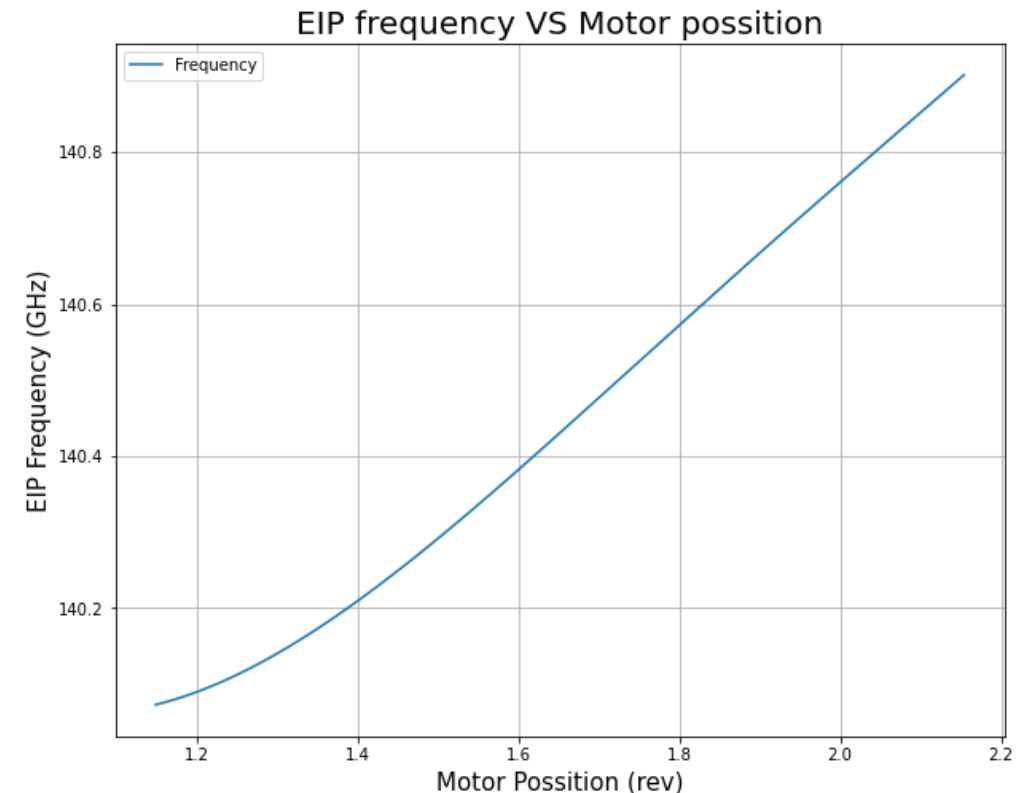
The frequency controlling unit

- The operating frequency range of the EIO is set 140 GHz- 141 GHz. This was selected by setting the cathode voltage to 9.88 kV and anode voltage to 4.44kV
- The positive and negative polarization frequency for NH₃ is around 140.135 GHz and 140.453 GHz
- The EIO is coupled to a 5-phase stepper motor. 1000 steps -> 1 revolution
- 1 step -> 0.001 GHz when operating in full step configuration
- The rotary potentiometer shows the absolute position of the motor.
- The window comparator circuit protect the EIO from over turning



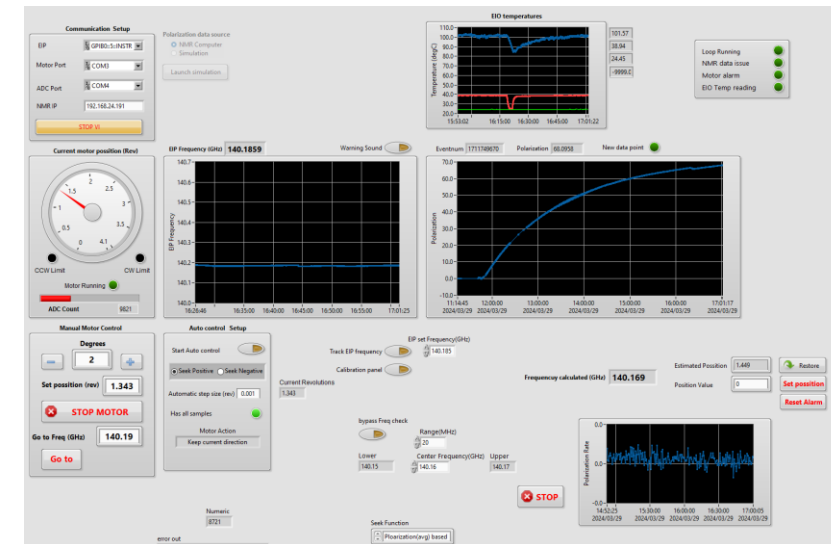
The frequency controlling unit

- The real-time frequency value of the microwave is provided by the EIP frequency counter.
- However, due to the high cable length (over 25 meters) between the EIP and the EIO, the EIP occasionally encounters issues, resulting in the frequency value being unavailable.
- To address this, we recorded the motor position versus the output frequency and successfully created a reliable map between the motor position and the EIO frequency

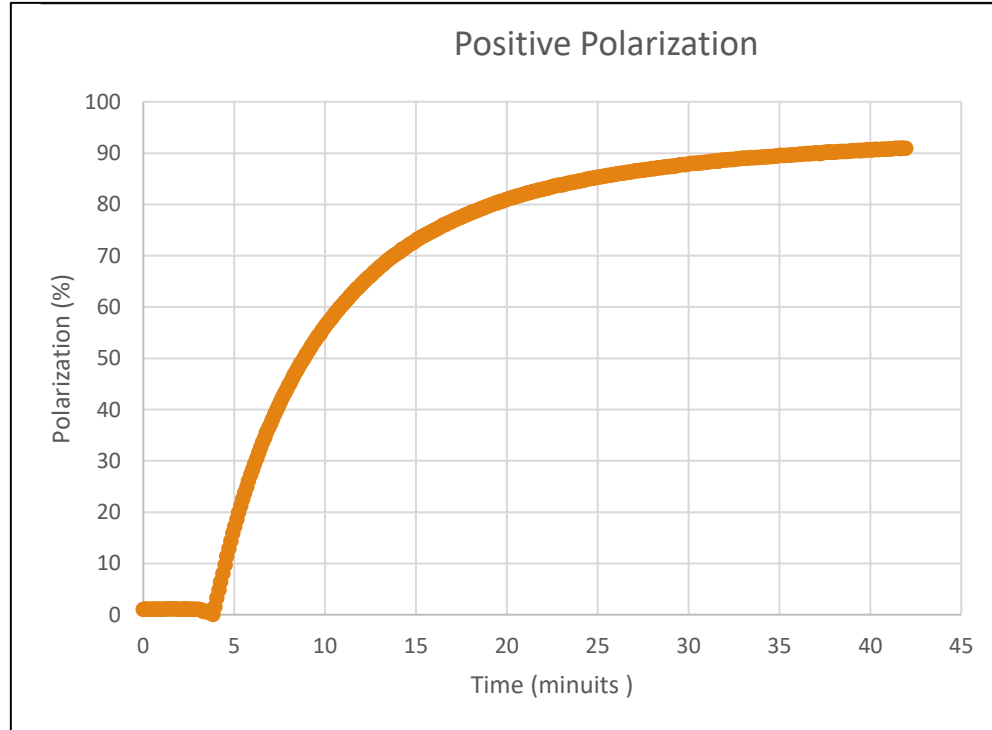


The frequency controlling unit

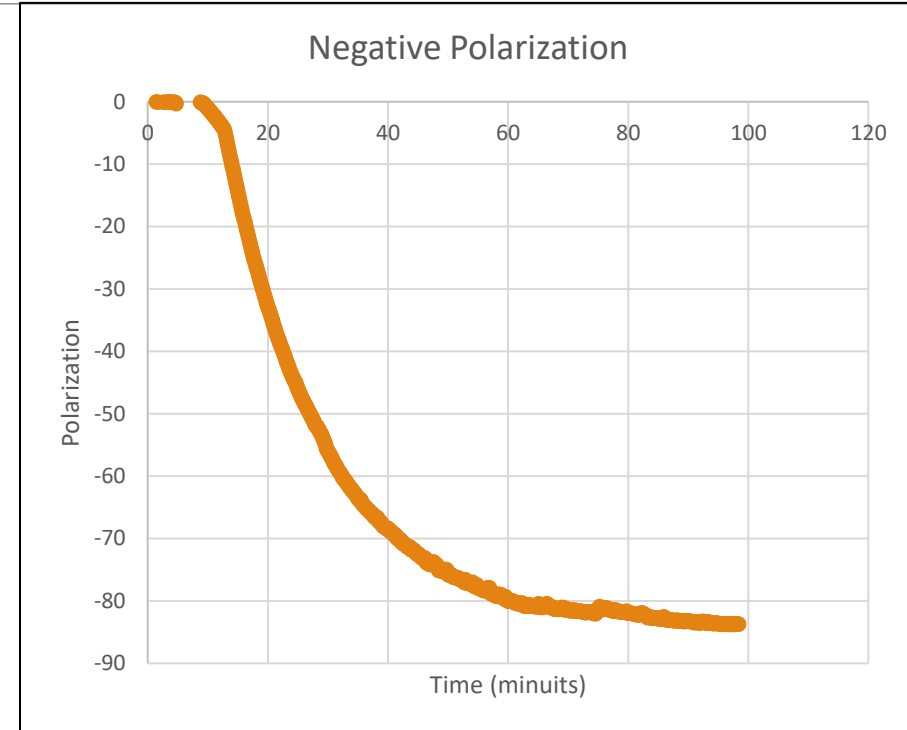
- The software interface continuously captures real-time polarization data from the NMR system.
- Users can control the microwave frequency either manually or automatically.
- An automation algorithm adjusts the output frequency to maintain maximum polarization, supporting both negative and positive polarization states.
- The system also continuously monitors the setup and generates voice warnings in case of a microwave signal loss.



Polarization results



Optimum frequency is around 140.14 GHz



Optimum frequency is around 140.43 GHz

The graph confirms the automation algorithm working fine for both positive and negative polarization

Power consumption estimation

The power calculated biased on the liquid helium boil off from the fridge nose

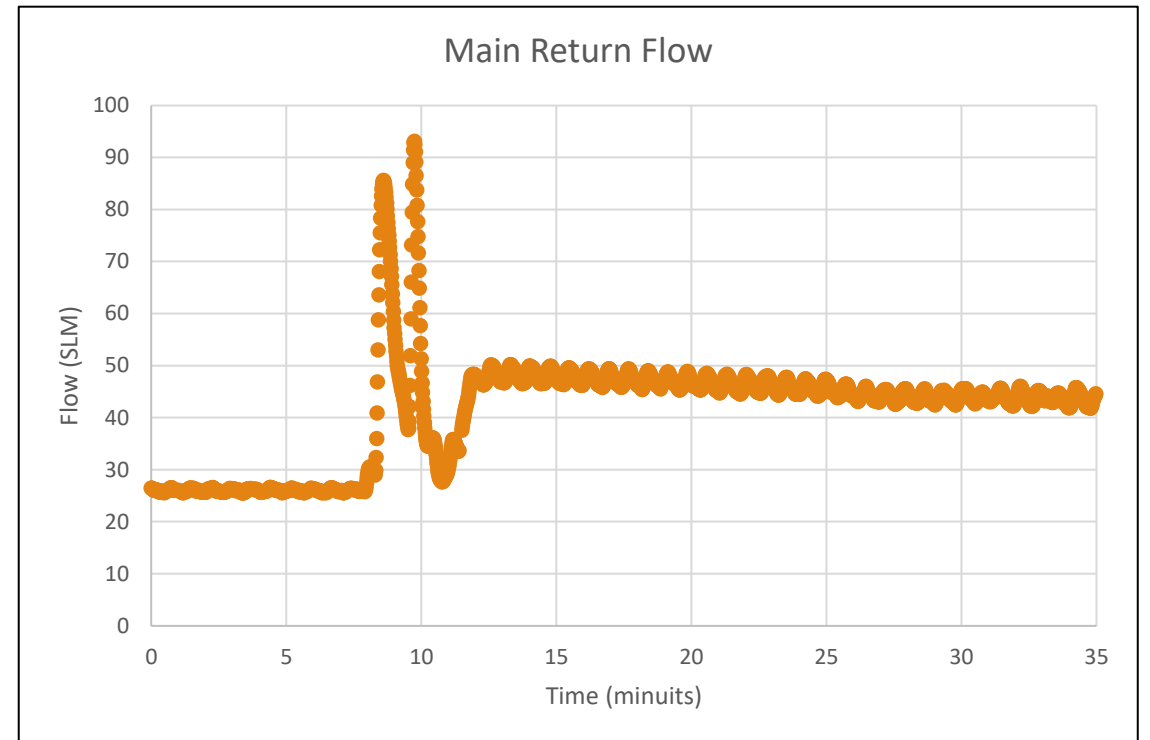
Helium boil off without microwave : 26.35 SLM

Helium boil off with microwave : 46.04 SLM

Microwave power : 1.2 Watts

Even after the attenuator the microwave power is too high to run the system sustainable.

A variable attenuator will be added to control the power



Summery

- The microwave system performed well during the beam commissioning
- The frequency optimization algorithm was successful
- We will look for a variable attenuator to minimized the microwave power further
- Will try the frequency modulation to improve the microwave profile in the horn

Thank You



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